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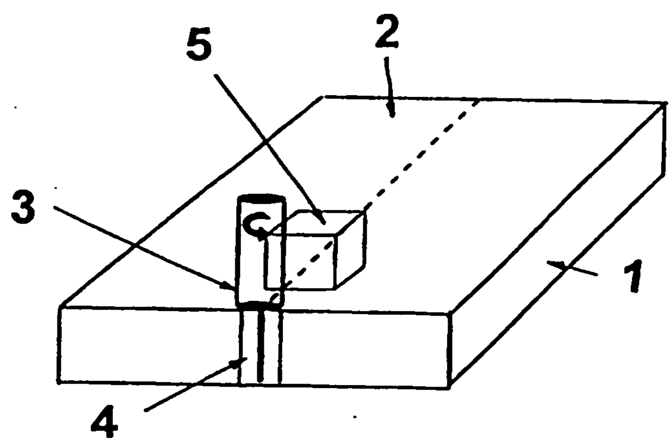
(54) Title: MODIFIED FRICTION STIR WELDING

(57) Abstract

A modified method of friction stir welding of members applying a non-consumable rotating probe further comprises a preheating of the assembled members prior to the welding operation. A welding apparatus is also disclosed provided with a primary heat source attached to the probe, preferentially a high frequency moving induction coil.



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"Modified friction stir welding"

The present invention relates to friction stir welding and more particularly to a modified method and an apparatus improving the welding process parameters.

Friction stir welding is a new friction welding process. The principles of the process and applied apparatus as disclosed by WO 93/10935 are based on a relative cyclic movement between a non-consumable probe of a harder material than the workpieces to be joined and the workpieces. Urging the rotating probe into the assembled adjacent workpieces along their joining line creates a plasticised region in the workpieces due to a generated frictional heat. Thus no heat is generated as in conventional friction stir welding due to a relative motion between the workpieces to be joined. This new welding method, having the advantage of solid state bonding, has been successfully implemented on providing plate and profile joints not previously feasible.

However, some drawbacks in terms of productivity and joint quality have been experienced due to the fact that the design of presently applied rotating welding tools (probe) is a compromise between two different demands/functions of the tool:

- (pre)heating of the material to a certain minimum temperature in front of the tool, and
- the mechanical stirring (commingling) of plasticised material from each side of the joint.

It is therefore an object of the present invention to provide a modified and improved method of friction stir welding resulting in increased productivity maintaining high joint quality for a wide range of materials, e.g. for high strength Al-alloys.

Another object of the present invention is to provide a novel apparatus adapted to a high speed friction stir welding.

These and other objects of the invention are met by provision of the modified friction stir welding method and a novel welding apparatus as defined in the attached patent claims 1 and 5, respectively.

Other objects, specific features and advantages of the present invention will become apparent from the following detailed description of the preferred embodiments of the invention with reference to the accompanying drawings, Figs. 1-2, where

Fig. 1 illustrates schematically the basic principle of the improved friction stir welding,

Fig. 2 is a picture of a weld seam achieved by a preferred embodiment of the welding apparatus according to the present invention.

The friction stir welding as described in WO 93/10935 is incorporated herein by reference to the extent consistent with the present invention.

A detailed description of the present invention embodied by way of examples by novel apparatuses usable in the modified friction stir welding follows below.

Referring to Fig. 1 two plate members 1,2 are shown schematically being welded together by means of a rotating probe comprising a non-consumable pin.

According to the present invention, in order to facilitate formation of the welded seam 4, a primary heat source 5 is attached to the welding apparatus in front of the rotating probe in the friction welding tool 3.

According to the preferred embodiment of the apparatus according to the invention a moving induction coil is applied as the primary heat source 5 to provide controlled heating of a limited volume of the welded material beneath the tool shoulder to plasticise the material. Thus the main function of the rotating pin is to control the flow pattern of the preheated material and to break up oxide skin introduced from the welded members.

This separation of (pre)heating and mechanical stirring of the plasticised material results in a dramatical increase in the welding travel speed and thus a higher productivity maintaining high quality welds.

Furthermore, the use of a primary heat source allows for melting of eventually added filler material if deemed appropriate for the actual welding.

Example

Stir welding trials according to the invention were performed on 5 mm thick plates extruded in AA6082.50-T5 Al-alloy applying a mobile induction heating system operating within a power range of from 20 to 70 kW as the primary heat source. The preheating temperature imposed on the welded members by an induction coil located 20 mm in front of the welding tool was in a range of 420°C to 460°C, corresponding to the conventional preheating temperature of billets in an extrusion process. The applied welding travel speed was increased (doubled) to 2 m/min. As it appears from Figure 2 showing a picture of welds received in the trial

while friction stir welding without preheating at this speed results in not satisfactory weld seam quality, area A in the picture, the induction preheating provided a good quality smooth welds (area B). None of the other parameters have been changed during the trial.

The achieved mechanical properties (strength, elongation) are similar to the properties of "conventional" friction stir welds provided by lower welding speeds, or at similar speeds but on smaller thicknesses of the welded plates (3 mm).

Furthermore, apart from doubling the welding travel speed the actual force applied on the welding tool (friction stir energy input) is reduced by approximately 50%.

Thus, compared to conventional friction stir or high frequency induction welding of aluminium alloys, the modified friction stir welding process has the following advantages:

- Higher productivity because of the increased welding speed.

- Reduced problems with surface cracks, oxide contamination and other weld defects due to better temperature control and improved tool design with respect to material flow. This makes the process more reliable in terms of weld quality.

- Reduced problems with heat affected zone (HAZ) softening owing to the use of a more concentrated heat source in combination with extensive plastic deformation of the parent material. Post weld heat treatment may therefore be avoided.

- Reduced problems with distortions and residual stresses because of a low heat input per unit length of the weld. This, in turn, may eliminate the need for heavy clamping systems and increase the fatigue strength of the joint.

- Improved flexibility because of the reduced weight of the welding equipment. The development of a light and portable system makes the modified friction stir welding process suitable for automatic welding of aluminium extrusions.

- Possibility of adding filler material where needed during processing.

Thus the induction heating, being a non-contact heating method, gives a better control of the material to be heated within a well defined area. Furthermore, thanks to the fact that the heat source is cooler than the heated material, the temperature regulation is both very rapid and accurate.

However, for a satisfactory/efficient heating it is necessary to have strict control of the current path in the joined-to-be members. The generated current has to be separated on each side of the joint area between the members in order to avoid the current from flowing across the split/contact line of the adjacent pre-assembled members.

In order to achieve their goal an induction coil ensuring the same current direction on each side of the split provides controlled return of the "outside" current stream(s). This current distribution in the adjacent joined-to-be members further prevents formation of sparks in the split area (safety aspects and avoiding of surface damage) and formation of non-beneficial magnetic fields.

Apart from the above disclosed and discussed induction preheating other primary heat sources could be applied in the modified friction stir welding according to the present invention. Thus laser means are suitable as the primary heat source, e.g. Nd-YAG laser could advantageously be applied in friction stir welding of Al-alloys or any other conventional heat sources ensuring a controlled preheating of members.

Claims

1. A method of friction stir welding of members comprising steps of urging and securing the members together, entering such assembled members along their joining line by a probe under rotating movement of the probe causing a flow of locally plasticised material from the adjacent assembled members both perpendicularly and vertically to the longitudinal extension of the assembled members and finally solidification of the plasticised material behind the probe,
characterised in that
the adjacent members are preheated along their joining line close to the plasticising temperature of the members by means of a primary heat source located in front of the probe.

2. Method according to claim 1,
characterised in that
the adjacent assembled members are preheated applying a moving induction coil as the primary heat source to plasticise material of the adjacent members.

3. Method according to claim 2,
characterised in that
high frequency induction heating is applied to weld Al-alloy members.

4. Method according to claim 1,
characterised in that
the adjacent assembled members are preheated by means of laser as the primary heat source.

5. Apparatus for friction stir welding of members comprising a non-consumable probe (3),
c h a r a c t e r i s e d i n t h a t
the apparatus is further provided with a primary heat source (5) located in front of the probe.

6. Apparatus according to claim 5,
c h a r a c t e r i s e d i n t h a t
the primary heat source (5) is a high frequency moving induction coil ensuring a controlled current distribution pattern in the joined-to-be members .

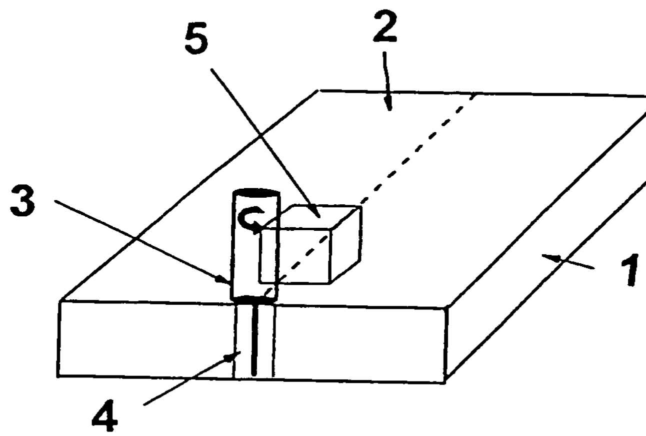

Fig. 1

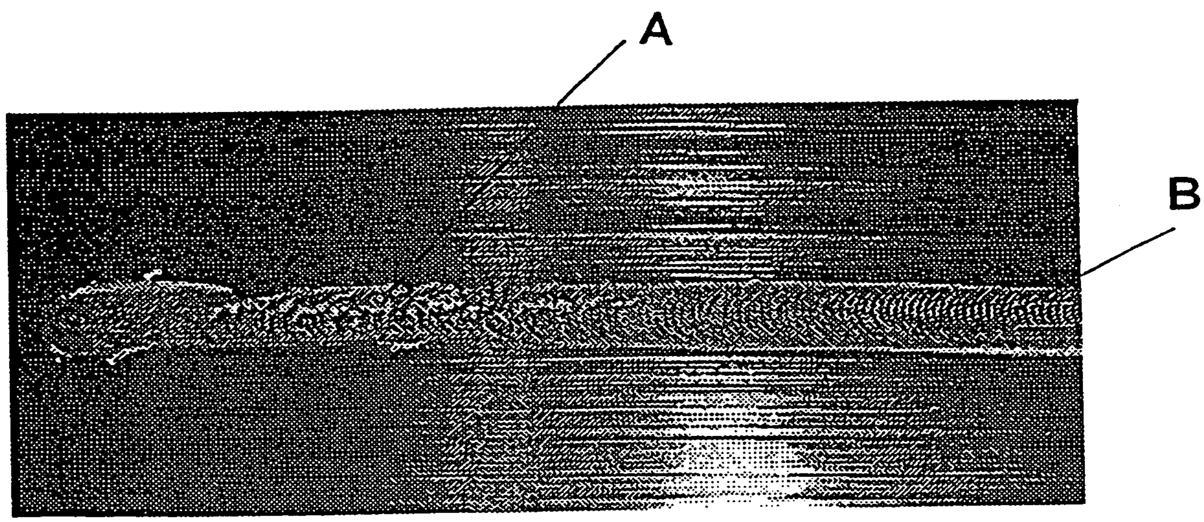

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00042

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B23K 20/12
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EDOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4144110 A (JANE LUC), 13 March 1979 (13.03.79), column 2, line 45 - column 3, line 44, figures 1-14 --	1
X	US 3779446 A (JEROME H. LEMELSON), 18 December 1973 (18.12.73), column 6, line 37 - column 7, line 25; column 9, line 44 - line 56, figures 5,6 --	1
P,X	WO 9845080 A1 (ESAB AB), 15 October 1998 (15.10.98), page 6, line 10 - page 6, line 27, claim 1 --	1-3

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 April 1999	06 -06- 1999
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

07/04/99

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